CHAPTER 7

Injury Control for Physically Active Men and Women

Joseph J. Knapik and Rebecca L. McCollam

INTRODUCTION

A physically active lifestyle is encouraged by almost everyone involved in health care. Moreover, experts claim that exercise does just about everything from extend longevity to improving the quality of life. These claims are well supported. Dr. Ralph Paffenbarger reported in 1986 that former Harvard University students had a lower risk of mortality from all causes if they exercised in their leisure time.[1] Death rates declined steadily as physical activity increased. In other research, Dr. Barbara Sternfeld concluded after a comprehensive look at the literature that individuals who were more physically active had lower risk of developing colon cancer and possibly breast cancer.[2] Dr. Kenneth Powell and his coworkers at the Centers for Disease Control and Prevention also comprehensively reviewed articles published on physical activity and chronic diseases.[3] Their work revealed that in addition to positive effects on longevity and cancer, physical activity reduced the risk of coronary heart disease, reduced symptoms of depression, and improved mood states.[3] Given all these beneficial effects of physical activity, it is no wonder that exercise is strongly promoted.

However, what is seldom considered in discussions of exercise is the potential for injury. That activity increases injury risk should not be surprising since there are physical hazards inherent in just about anything you do. When you get out of bed in the morning, you run the risk of twisting your body the wrong way and hurting your back. When you brush your teeth, you may accidentally cut the gums of your teeth. Driving to work in the morning, you risk a motor vehicle accident.

Like these activities of daily living, exercise has its own set of risks. This can be illustrated by our findings among senior military officers at the U.S. Army War College in Carlisle, Pennsylvania.[4] These officers averaged 43 years of age and were very active, participating in softball, volleyball, basketball, and other physical activities. They were also required to pass the Army Physical Fitness Test twice during the academic year, so most officers ran and performed calisthenic-type exercises. We found that 56% of these officers suffered at least one injury during their 10-month stay at the War College. Where a cause of injury could be determined, 77% were due to sports or exercise. Fortunately, most of these injuries were relatively minor, with only 23% resulting in some physical limitation and none of them causing permanent disability.

It is prudent to balance the benefits of physical activity against the risk of injury. It may even be possible for you to tip the balance in your favor, if you understand what increases your risk of injury and you act to minimize these risks. We will help you do this by discussing various risk factors that will increase your likelihood of injury and then offering practical suggestions on how to avoid injury. We will then provide some general guidelines for injury first aid that will help you heal faster should you suffer an injury. Finally, we will review the types of injury commonly encountered by physically active people. Our purpose is to provide you the tools to enjoy the benefits of physical activity while reducing your odds of suffering an injury.

RISK FACTORS FOR INJURIES

Over the last 20 years considerable progress has been made in identifying factors that put individuals at risk for injury. A list of demonstrated risk factors is provided in Table 1.

Some risk factors are "extrinsic," meaning they are characteristics of the environment in which you are exercising. Other risk factors are "intrinsic," meaning that they are characteristic of you, the active person. In this section we will discuss these risk factors and explain some common sense ways you can use this information to reduce your risk of injury.

EXTRINSIC FACTORS
Running distance
Running shoes
Weather

INTRINSIC FACTORS
Prior physical activity
Physical fitness
Aerobic fitness
Muscular endurance
Flexibility
Past injuries
Cigarette smoking
Life and job satisfaction
Gender
Age
Anatomic factors
Foot arch height
Knee alignment

Table 1. Risk Factors for Exercise-Related Injuries

EXTRINSIC RISK FACTORS

Running Mileage . Studies of runners and basic trainees have shown that as running mileage increases so does the risk of injury.[5] It would thus seem wise to limit your mileage to the minimum required for health and/or fitness. But what is this level? The real answer is that we do not know; however, a study by Dr. Michael Pollock provides some insight.[6] Table 2 shows the association of frequency and duration of running with injury incidence from Dr. Pollock's study.

Exercise Frequency			Exercise Duration		
Frequency (days/wk)	Injury Incidence (%)	Aerobic Fitness Improvement (%)	Duration (min/day)	Injury Incidence (%)	Aerobic Fitness Improvement (%)
0	0	-3.4	0	0	0.7
1	0	8.3	15	22	8.7
3	12	12.9	30	24	16.1
5	39	17.4	45	54	17.0

Table 2. Effects of Frequency and Duration of Running on Injury Incidence and Aerobic Fitness

If you look at the number of exercise days per week (exercise frequency) you can see that more days result in more fitness, but injury rates increase disproportionately. If you look at the amount of time spent exercising each session (exercise duration), you will note that there is little change in fitness after 30 minutes of exercise, but injury rates more than doubled at 45 minutes of exercise. Thirty minutes per exercise session is not a magic number, but it might be a good guideline to keep in mind. The amount of exercise you can perform without significantly increasing the risk of injury will also vary based on intrinsic risk factors discussed later.

Figure 1. Stress Fracture Incidence by Age of Running Shoe

Running Shoes. As every athlete knows, there comes a time when it is necessary to replace one's tried and true running shoes due to age and wear. However, this need probably arises much sooner than many would expect. We often take our athletic footwear for granted, seldom examining the degree of wear and tear imposed on them. Dr. Lytt Gardner and his co-workers studied Marine recruits at Parris Island and found that those who began training with newer running shoes had a lower incidence of stress fractures, as shown in Figure 1.[7]

Dr. Gardner speculated that aging of the shoe adversely affects its mechanical support and cushioning ability. This suggests that frequent examination of athletic shoes and replacement when they show signs of excessive wear may reduce the incidence of some types of injury. A good rule of thumb is to replace your shoes when you have worn through the first bottom layer (good running shoes have multiple bottom layers). This often occurs on the outside edge at the back of the shoe. In addition, if the upper portion of the shoe is so damaged that you experience excessive lateral motion, it may be time to look for a new pair. Check your shoes often and replace them when worn.

Although athletic shoe companies may tell you that one pair of shoes is better than another for avoiding injuries, no studies thus far have validated this claim. However, there are some common-sense guidelines you can follow when purchasing your shoes—a most important piece of equipment. All athletic shoes should provide good shock absorbency and traction, and be flexible in the forefoot (where the foot bends in normal walking). The back of the shoe should hold to your heel, but you should be able to place a finger between the back of the shoe and the back of the heel to assure the shoe is not too small. Stand on your tiptoes and if the shoe slips off your heel try a smaller size. Modern athletic shoes should be comfortable when you first put them on or after just a few minutes of walking. There is no break-in period. Shop for shoes at the end of the day, because your feet are likely to be larger. Try on the shoes with the socks you will wear during activity. Most importantly, select shoes specifically designed for the activity you are performing. Running shoes, for example, are designed for forward motion and generally do not have proper lateral support for sports that require side-to-side movement like racquetball or tennis.

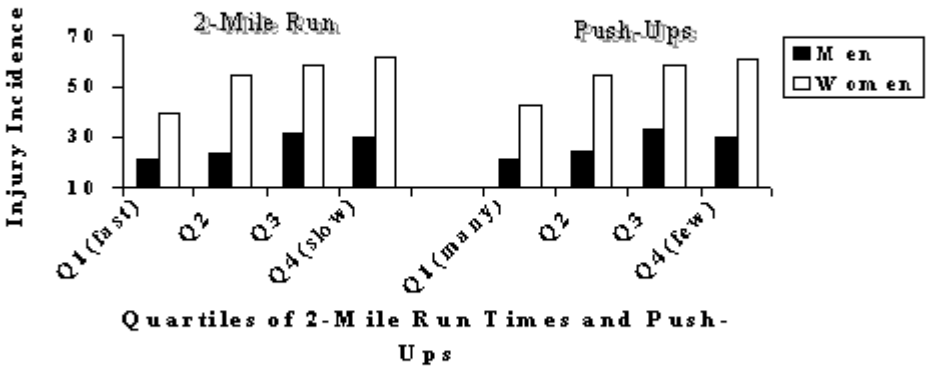
Weather . If you have exercised in warmer weather, you know that compared to cooler weather the effort is much greater and fatigue sets in much faster. Injuries to muscles, bones, and joints have been shown to increase for both men and women as the temperature rises.[8] It may be prudent to slow down and possibly exercise for a shorter period of time when the weather is hot and/or humid.

INTRINSIC RISK FACTORS

Prior Physical Activity **.** Several studies have indicated that those most vulnerable to injury are those who have not been physically active in the past.[9] It may be that those who have been less physically active have not developed the stronger bones, muscles, and joint structures that tend to resist injury. If you are just starting an exercise program, it is best to follow

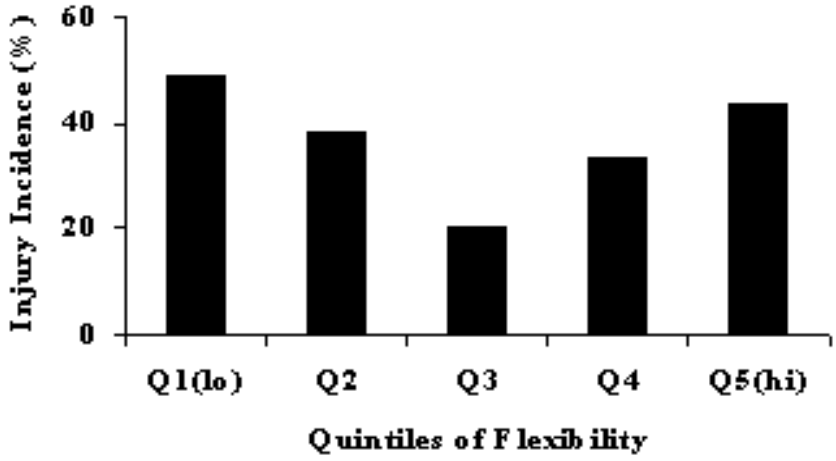
the time-honored advice of increasing your exercise duration and intensity slowly over time. If you have been exercising regularly, your risk of injury may be lower. However, even if you have been exercising on a regular basis, take care in further increasing the duration or intensity of your activity. More suggestions on how to progress in an exercise program will be given later.

Figure 2. Association of Maximal Effort Two-Mile Run Times, Push-Ups, and Injury



Aerobic Fitness and Muscular Endurance. Physical activity and physical fitness often go hand in hand because if you participate in activity of sufficient intensity, frequency, and duration, you will increase your overall fitness. Low aerobic fitness and low muscular endurance are also associated with higher injury risk as revealed in Figure 2, which shows increasing injuries for those performing more poorly in the two-mile run (aerobic) and push-ups (muscular) during maximum efforts.[10] These findings also support the practice of progressing slowly in a program of physical activity. As you build fitness, your injury risk will decrease.

Figure 3. Association of Flexibility and Injury



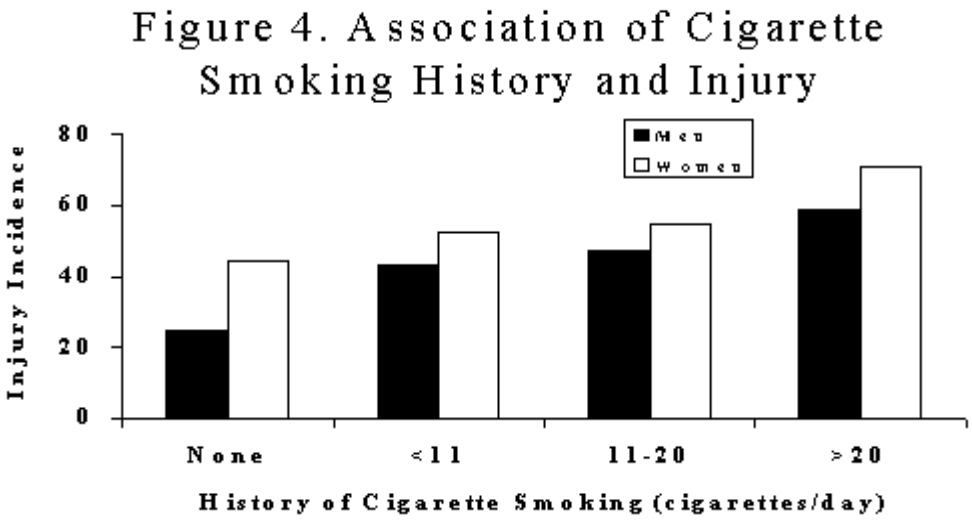
Flexibility, Stretching, and Warm-up. It is often thought that more flexibility leads to less injury and less flexibility leads to more injury. Recent findings suggest that this is only partly true. A number of studies now indicate that those at both extremes of flexibility are at higher risk of injury, as shown in Figure 3.[11] Popular opinion has it that stretching is an injury-prevention technique, but this notion is one of the enduring myths in sports medicine. Two well-controlled studies have shown that stretching does not reduce injuries. Dr. W. H. VanMechelen, a Dutch sports medicine physician, compared a group of runners who stretched (before and after running) with those who did not. At the conclusion of the study, there were no differences in injuries between the two groups.[12] More recently, Dr. Rodney Pope and his coworkers compared groups of Australian basic trainees who stretched prior to exercise to those who did not. Again, there were no differences in injury rates between the two groups. [13]

Does this mean that you should not stretch before and after exercise? No, it just means we currently have no evidence that stretching will either help or hurt when it comes to injury control. On the other hand, warming-up before exercise may have some favorable physiological effects that could reduce injuries. These include an increase in body temperature and blood flow, which allows the muscles to contract more forcibly and move with less effort. Warm-up may also result in modest increases in flexibility in the joints involved in the movements. [14]

Although there are a number of different types of warm-ups, the task-specific type may be most effective. You can create a task-specific warm-up for almost any activity by mentally picturing the types of movements you will make during the activity itself. After you have envisioned these movements, perform them, gradually at first, then increasing intensity over time. For example, if you are going out for a run, you might start out by walking, increase the pace to a fast walk, break into a jog, and then increase slowly up to your training speed. If you are playing volleyball, you could warm up by practicing sets, spikes, digs, and blocks, increasing in intensity over time. Basketball players can practice shooting, running, and dribbling, increasing the activity intensity as game time approaches.

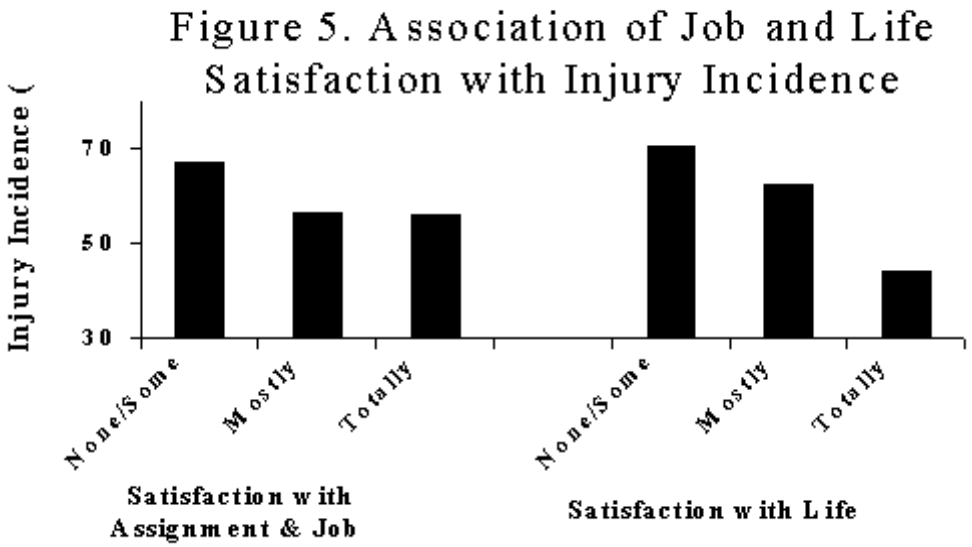
It is a good idea to perform a secondary warm-up if you have been inactive for awhile or if you are involved in sports that have intermittent activity. For example, as a batter in softball, envision the tasks you may have to perform. These are swinging at the ball and running the bases. To warm up, you could practice swinging the bat (or bats) and performing some short sprints or running in place. In sports like volleyball and basketball, where the action is relatively continuous, you may be less susceptible to cooling down. However, if you enter the game from the bench you might practice some game-like movements before the whistle blows.

Past Injuries . It is quite possible that a past injury may increase risk for future injury. Senior military officers at the Army War College who suffered an ankle sprain in the previous 5 years were more likely to suffer another sprain.[15] This tendency has also been found in other groups of active people such as soccer players and soldiers.[16] If you have had a prior ankle sprain and are physically active, see a health care provider, who may recommend an appropriate brace. Certain types of ankle braces have been shown to reduce the likelihood of reinjuring the ankle. [17]



Cigarette Smoking . Another factor that increases the likelihood of injury is cigarette smoking. This has been confirmed in many groups, ranging from industrial workers to infantry soldiers.[18] Figure 4 suggests that the more cigarettes you smoke, the higher your risk of injury becomes. However, the reason for this relationship is not clear. Psychosocial factors such as greater risk-taking behavior and specific cognitive changes (e.g. lack of attention, altered mental state induced by nicotine) may play a role. Also, smokers do not heal as quickly as non-smokers and have impaired immune systems, which could increase injury rates.[19] Regardless of the reasons for this relationship, you should be aware that if you use tobacco products your risk of injury will be higher.

Life and Job Satisfaction . Psychological factors also appear to play a role in injuries. Figure 5 shows the association of injury incidence with life and job satisfaction among senior military officers at the Army War College.[20] Individuals who arrived at the Army War College reporting greater job satisfaction or greater overall life satisfaction were at lower injury risk during their 10-month assignment. This suggests that a more positive outlook on one's current may protect against injuries.



Gender and Age . Several studies have shown that women are at greater injury risk than men, and that older individuals are at higher injury risk than younger ones.[21] However, all these studies were conducted in U.S. Army basic training, where everyone is required to do the same activity at a similar pace. In the civilian athletic world, men and women generally compete separately, at their own pace, and experience a similar injury risk.[22] Additionally, in environments where older individuals are likely to be able to control the intensity of their activity, older individuals actually have lower injury rates than younger ones.[23] The message is fairly clear: control your own exercise program and do not be concerned with keeping up with others. Women, in general, should exercise less intensely than men; older individuals should exercise less intensely than younger ones. Of course there will be the unusual woman who can successfully compete with men, or the 60-year-old marathoner who can still run the distance in 3 hours. However, these are the exceptions and you should not let others control how long, how often, or how intensely you exercise.

Anatomic Factors . As with gender and age, there is little that can be done about one's inherent anatomic features. However, like age and gender, a knowledge of what may put you at increased risk may help you design your exercise program and understand the limits of your body. Individuals with high foot arches are at increased injury risk compared to individuals with normal arch heights.[24] Individuals who are knock-kneed (i.e. have their knees turned more toward the midline of the body) are also at higher risk of injury. Bow-legged individuals appear to have injury risk similar to that of persons with normally aligned knees.[25] Remember, not everyone who has these conditions experiences injuries, but these conditions do increase your risk. You may have to be more careful with your exercise intensity and the types of exercise you perform if you have these anatomic features.

You can reduce your risk of injury by understanding and modifying the risk factors cited above. Remember that, all other things being equal, the individuals at highest risk of injury will be those who are less physically active, are less physically fit, have either high or low flexibility, have had a prior ankle sprain, are smokers, have lower life satisfaction, are female, are older, and/or have knocked knees or high foot arches. However, not all things have to be equal. You can control the likelihood of injury by following the general guidelines above after adapting them to your experience.

OTHER INJURY CONTROL STRATEGIES

In addition to modification of risk factors, there may be several other methods of controlling injury. These include appropriate progression in your exercise program, the use of protective equipment, understanding the warning signs of impending injury, and a program of spinal stabilization. Many of these injury control strategies have not yet been specifically tested for their injury reduction capability, but common sense and anecdotal evidence suggest they may be effective.

Exercise Progression

Probably the biggest single training mistake most people make is performing too much exercise before the body is ready for

it. The body adapts to the stress of physical activity by increasing the strength of the heart, muscles, bones, ligaments, tendons, and other structures.[26] Too much stress too soon will likely result in a breakdown in one or more of these structures. E. C. Frederick tells us that "we should approach [exercise] not as if we were trying to smash our way through some enormous wall, but as a gentle pastime by which we can coax a slow continuous stream of adaptations out of the body." [27]

When it comes to exercise, people have different tolerance levels based partly on their injury risk factors. This makes it difficult to provide strict exercise levels that will result in health adaptation and avoid unhealthy breakdown. We recommend following the 10% rule if you are just starting an exercise program. That is, you can increase either the duration or the intensity (not both) of your exercise program by 10% each week. If you run, for example, you could exercise for a 10% longer period of time (duration) or complete a standard distance 10% faster (intensity). If you are a weight lifter, you could do 10% more sets (duration) or increase the weight 10% (intensity).

You will eventually reach a point where you will no longer be able to achieve a 10% per week improvement. This is because the body has inherent limits that you cannot exceed. Even the most elite athletes do not improve indefinitely. You can reach a point where a 5% or even 1% improvement is difficult to achieve. Figure 6 shows a sample of the rate of improvement that might be expected if one continues to increase the duration or intensity of exercise over a period of weeks. Improvements of 10% are easily achieved early in your exercise program, but the expected improvements level off later in the program. Only small improvements over a period of months or years are possible once you have been exercising continuously for a long time.

Another approach to exercise progression often used by athletes is periodization.[28] With this method, you increase the intensity or duration of the exercise in preparation for a particular event like a road race, weight-lifting competition, or tennis tournament. After the event, you decrease the amount of exercise you perform to allow your body more time for rest and recovery. As the next event approaches, you again increase the amount of exercise you perform. You complete these cycles of peaking and resting with longer periods of lower exercise volume in the off-season.

Of course, you may be interested merely in exercise for general health and fitness. If this is the case, remember the study by Dr. Pollock cited earlier.[29] Once you have reached the level of 30 minutes of exercise, it might be best to simply maintain your program at that level and enjoy the long-term health benefits.

PROTECTIVE EQUIPMENT

Depending on the sport in which you participate, some types of protective equipment can considerably reduce your risk of injury as well as pain and discomfort. In this section, we shall discuss the types of protective equipment available and provide you some practical guidelines for selecting appropriate equipment for different sports.

Bicycle Helmets. Bicycle helmets are designed to protect the rider’s head in case of an impact. Several well-conducted studies performed by Dr. Diane Thompson and her co-workers conclude that "helmets reduce the risk of head injury by 75%, brain injury by 88%, and severe brain injury by at least 75%."[30] They also note that helmets reduce facial injuries by two-thirds. Given these odds, it seems prudent to wear a helmet when bicycling.

Helmets are of three major types: (1) those composed only of polystyrene (like styrofoam), (2) those that have a polystyrene liner covered with a thin plastic shell, and (3) those with a polystyrene liner with a thick plastic shell. Helmets with shells appear to provide better protection. Helmets should have several holes to provide good ventilation so you can dissipate heat coming off your head. In fact, many models have the ventilation holes oriented to take maximal advantage of the airflow produced by bicycling.

When fitting the helmet, ensure that the straps are adjusted to hold the helmet firmly but comfortably on the head and that there is a minimum of movement. Shake your head once you have fitted the helmet to assure it does not drift in any direction. Adjust the straps so they do not pinch the ears and the strap buckles do not irritate your skin. In February 1998, the U.S. Consumer Product Safety Commission (CPSC) issued federal safety standards for bicycle helmets that take into account shock absorbency and strap strength. Look for the CPSC certification label in helmets you are considering. Other organizations with voluntary standards (on which the CPSC standards are based) include the American National Standards Institute (ANSI), the American Society for Testing and Materials (ASTM), and the Snell Memorial Foundation. If your helmet sustains a significant impact, replace it immediately because its ability to absorb impact is thereby reduced. [31]

Protective Eyewear. If you play sports like racquetball and squash, you are already familiar with how fast the ball moves and the possibility of its contact with other players and equipment. In this environment, there exists a risk of eye injury and

loss of vision. Goggles and faceguards have been shown to reduce eye injuries in many sports.[32] When you shop for appropriate protective eyewear, avoid open eyeguards (i.e. those that do not have lenses) since documented cases of open eyeguards reveal that objects can still cause eye injury to the wearer.[33] Eyewear should have polycarbonate lenses and an anti-fog coating to prevent condensation build-up from perspiration. Currently, look for eyewear certified by the ASTM. ASTM F803.97 certifies eyewear appropriate for racquet sports and baseball protection, ASTM F1776-97 for paintball protection (paintballs are used in some combat simulation games). There is also the ASTM F659-92 standard for alpine skiing. Since 1999, you may find eyewear certified by the Protective Eyewear Certification Council (PECC), which assures not only testing to ASTM standards, but also a quality control test in an independent laboratory.[34]

In-Line Skating Protection. In-line skating has become increasingly popular with young and older athletes alike. The wrist is the most common injury location with this sport, probably due to falls on the outstretched hand. Preliminary studies indicate that the use of wrist guards can reduce the odds of wrist injury by sixfold. Considering that many falls also involve the knees, elbows, and head, protective devices for these body parts may also be a good idea. Protective devices can usually be found anyplace where skates are purchased. Thus far, no independent standards have been developed for this type of equipment. [35]

Sports Bras. If you are a woman and have experienced breast pain or discomfort during physical activity, you are not alone. In one survey, 56% of women reported sport-related breast pain and discomfort, much of this connected to excessive movement of the breasts.[36] Recently, there have been many developments in sports bras but there is little research on which types of bras are most effective.[37] Let your comfort be your guide and consider the following. There are two major types of sports bras, the compressive and encapsulation types. Compressive types limit movement by flattening the breasts against the body; this type may be most effective if you are an A or B cup size. The encapsulation type contains molded cups that hold each breast separate while providing support; if you are larger breasted (C or D cup), you may prefer this type. Regardless of the type of bra you choose, ensure that the bra limits breast motion while allowing comfortable breathing during the activities you perform.

Fabrics that incorporate blends of 50% cotton and 50% of another breathable material (like Lycra or Coolmax) may be the most comfortable. Breathable materials can increase comfort by forcing sweat away from the body. Watch for seams and buckles that may irritate if they are in contact with your body. Look for ample arm room (halter top types) that will not restrict your active arm movements or cause chafing. Finally, many sports bras are also labeled regarding their ability to provide specific amounts of support based on the type of sport. For example, certain sports bras will provide support only for low-impact activities such as walking or low-impact aerobic dance, whereas others are designed to provide additional support for high-impact activities such as running or jumping. Many sports bras are colorful, stylish, fashionable, and can serve as outerwear.[38]

Breakaway and Compressive Bases . In baseball and softball, most injuries are caused by sliding into base.[39] Breakaway bases are designed to dislodge when an individual slides into them and have been shown to substantially reduce sliding-related injuries.[40] Compressive bases are constructed to compress inward and downward and to absorb the force of a sliding runner, and these have also been shown to reduce sliding injuries.[41] Adapting rules to allow overrunning of second and third bases eliminates sliding altogether and may also reduce injury. If sliding is allowed, an instructional program on sliding technique will serve as an injury reduction tool.

You can obtain specific information on other protective devices in publications on the sport in which you are involved and by consulting sport and exercise professionals.

FEELING YOUR PAIN

We have all experienced the normal aches and pains associated with a physically active lifestyle. At their least severe, these pains are little more than the normal stiffness experienced on getting up in the morning or rising to your feet after being seated for a long period. Slightly more painful is the normal muscle soreness you might experience from a hard exercise session you had one to three days before. At the extreme is an outright injury that results in severe pain and limits your normal physical activity.

When dealing with aches and pains, you should use the experience you have gained with your body over many years of use. Some stiffness, discomfort, and soreness are inevitable when you exercise and shortly after the exercise period. Moreover, joint and muscle stiffness that resolves with exercise is common in mature athletes and is unrelated to injury. Excessive fatigue and an abnormal lack of enthusiasm for exercise may indicate that the intensity or duration of your activity is too great or that you have not allowed enough time for rest and recovery. Pay particular attention to pain that develops gradually and gets worse with each exercise session, since this is a major sign of an impending overuse injury.

Sharp or persistent pain that remains for a long period after exercise is the body's signal that something is wrong and a warning signal to slow down before things get worse. Obviously, you should consult a health care professional for any severe injury or for pain that persists after rest and first aid (described below).

You may be able to gain a general idea of the body tissues that may be injured by monitoring the course of pain. Pain that occurs at the start of exercise, disappears during exercise, and returns shortly after the end of exercise may be related to inflammation of soft tissues like tendons, muscles, and ligaments. Pain that persists during exercise and improves with rest may be related to a bone injury.

SPINAL STABILIZATION

Another method of reducing the possibility of injury is to strengthen the body's core musculature. These are the muscles in the trunk and back. Research related to trunk rehabilitation, better known as spinal stabilization, supports an aggressive approach to increase strength, endurance, and coordination of these core muscles.[42] In this section, we shall discuss the importance of the trunk and back muscles for injury control, and then provide some practical exercise suggestions to help you strengthen your back and trunk.

Why should we be concerned with our trunk and back muscles? One reason is that these muscles are critical to reducing low back pain and optimizing performance. Low back pain is a major health concern that has reached epidemic proportions in American society. The incidence of low back pain is staggering and growing 14 times faster than the population.[43] It is estimated that 60 to 80% of the general population will experience at least one episode of low back pain during their lifetime and that 70 to 90% of these individuals will develop significant back problems. Once an individual has low back pain, they are 7 to 10 times more likely to have recurrent low back pain. At any given time, 15 to 20 percent of the population will suffer with low back pain. Low back disorders do not discriminate; all occupations, social classes, and both sexes are equally affected. Spinal stabilization can help reduce the incidence of low back pain.[44]

A second reason we should be concerned with our core musculature is related to improving performance. The abdominal and back muscles form a supportive ring around the spine similar to a corset. Simply put, muscles have two basic functions, as movers or stabilizers. A mover permits motion to occur around a joint. Some muscles function only as movers, such as the rectus abdominis (the muscles in the center of the abdomen). The rectus abdominis allows the spinal movement involved in the sit-up. Not as obvious are the muscles that act as stabilizers to control or "brake" movement. These stabilizing muscles protect our joints from unwanted movement while maintaining proper posture and alignment. This braking effect allows for controlled, coordinated, and purposeful movement.

The braking action of the core muscles primarily serves two purposes. First, the spine and pelvis provide a solid, stable base of support for the attachment of the arm and leg muscles. Without a fixed foundation, using these muscles to power the arms and legs would be similar to pushing an object while standing on slippery ice. Secondly, when the core muscles apply the brakes, they promote balanced and controlled movement while maintaining the body's center of gravity within the core.

From this perspective, we see that the traditional sit-up does not adequately train the core musculature. A study conducted by the Australian army discovered that soldiers scoring the best on a timed sit-up test demonstrated poor functional control when attempting to hold the spine in stable positions.[45] The core muscles function to safely and effectively manage the daily stresses acting on the spine in a safe and effective manner. If the sit-up is the only training we perform for the trunk, we will be ill equipped for the challenges that face our bodies every day and at greater risk for back problems.

How do you go beyond the standard sit-up to train the core muscles? First, it is important to work those core muscles not challenged by the sit-up. Try the exercises below. The goal is to maintain the neutral spine position during each exercise independent of the position. To find the neutral spine position, first arch your back to full range, then flatten the back to full range. Repeat these movements slowly until you find a pain-free and stable position between the two extremes of movement. This is your neutral position. Do not allow your spine to move when performing the recommended exercises in this chapter.

Perform all exercises recommended below in a deliberate, slow, and controlled manner. Progress to faster movements as you improve your control with the exercise. Your breathing should remain slow and rhythmical. Gradually progress to performing each exercise continuously for 3 minutes. Do not focus on the repetitions; instead concentrate on proper technique until you experience muscle fatigue. At the onset of muscle fatigue, stop and change exercises. Perform each exercise a minimum of 3 times per week every other day. Since the trunk muscles are endurance muscles, you can safely work these muscles daily. Remember: Perfect practice makes perfect!

Secondly, you must compensate for the adverse effects of faulty body mechanics, poor posture, poor life-style habits, and repetitive sit-ups (particularly if performed too rapidly). In other words, balance the forces on the spine equally by performing exercises such as back extension and hip stretches. You can overcome the limitations of the sit-up through the following simple additions to your exercise program. The following basic exercises are suitable for anyone.

Supine Bridging. Lie on your back. Bend your knees to 90^0 with your arms at sides. Lift and lower your buttocks keeping your feet on the floor shoulder-width apart and maintaining the neutral position. In the up position, your hips and buttocks should fall midway between your shoulders and knees forming a straight line. Attempt to lift and lower your buttocks without losing the neutral position. Do not push up with your arms. Progress by holding the bridge position and spread your thighs approximately 18 to 24 inches. Do not let your trunk or pelvis sag when moving the legs in and out.

Supine Combination. Lie on your back. Bend your knees to 90^0 with your feet flat on the floor and your arms extended over your chest. Alternately lift (march) your legs off the floor while raising the opposite arm overhead with the thumb up, maintaining neutral position. Progress by raising both arms overhead and then adding light wrist/hand weights with overhead arm movements.

Lateral Lean "Sit-up of the Millennium." Lie on one side and prop up on your elbow with weight on the hip and forearm of the same side. Place opposite hand on your hip. Firmly press into the ground with your supporting arm while raising your trunk and hips off the floor forming a straight line with the body. Repetitively lift and lower in this position until muscle fatigue and repeat on other side.

Prone with Legs. Lie face down. Extend your arms overhead. Lift one leg at hip joint with knee joint straight, but not locked. Keep your pubic bones pressed to the floor while maintaining neutral position. Lower your leg and repeat with opposite leg. Progress by adding light ankle weights. Do not allow back to sag.

COMMON SENSE FIRST AID INJURY TREATMENT

Despite your best efforts, you may still experience some injuries. If this happens, your immediate goal should be to reduce the pain, swelling, and inflammation. One specific treatment protocol endorsed by many sports medicine professionals is called RICE—rest, ice, compression, elevation[46]. You can think of the RICE protocol as immediate first aid for many types of injuries. Anti-inflammatory medication may also be helpful in some injury cases.

Rest . Use rest to prevent further injury and allow the body sufficient time to proceed with its natural healing processes. The initial rest period should be 1 to 2 days for minor injuries, enough time to allow the inflammation to diminish. Healing severe injuries, on the other hand, may take several days to weeks. For mild injuries (both chronic and acute), rest is relative, requiring only a decrease in the intensity, frequency, and duration of activity. In some cases, you may be able to exercise parts of the body that are not injured. For example, a runner with a leg injury can still perform exercises involving the arms. As a rule of thumb, you can return to your normal exercise when your activity is relatively pain free. A sports medicine professional can also give you valuable information on how to continue training without additional injury and suggest rehabilitation programs.

Ice . Use ice to reduce swelling, inflammation, and pain. Ice placed directly over the affected area limits the fluids going into the injured area, deadens nerve fibers, and reduces muscle spasms. Ice is especially effective in the first 24 to 72 hours of the injury. The simplest way to apply ice is to put it into a plastic bag. Place a damp towel over the injured area, and then put the ice pack over the towel, allowing it to conform to the contours of the body. Avoid placing dry towels or plastic directly on the skin since these can cause ice burns. Ice should be applied only be for 20 minutes at a time. For acute temporary injuries, a cold pack can be applied every 2 to 3 hours for the first several hours; later, use ice twice a day. For chronic (long-term or recurrent) injuries, massaging with chunks of ice or ice frozen in paper cups can be effective. Apply slow circular strokes for up to 20 minutes, 2 to 3 times per day.

Compression . Compression reduces internal bleeding and swelling of the affected area. Elastic wraps (e.g. Ace bandages) can be used for this purpose. Avoid wrapping the elastic too tight, and guard against the elastic rolling up; either of these missteps can cut off your circulation. Constant monitoring is important. You can combine compression and ice by placing the ice over a damp elastic wrap. Do not use elastic wraps over an active joint (e.g. knee when running), since the wrap can easily roll up and reduce circulation.

Elevation . Elevation reduces swelling and the entry of fluids into the affected area. The injured area should be raised above the level of the heart (i.e. mid-chest). Place the injured area in a comfortable position so you can maintain the elevation with minimal distress.

Anti-Inflammatory Medication **.** Many anti-inflammatory medications may be obtained without a prescription. Generic medications with names like aspirin, ibuprofen, and naproxen can help reduce pain and inflammation. You should not use these medications within the first few days of injury because they may interfere with healing processes. These medications are best for chronic conditions like plantar fasciitis or tendinitis.

No medication is without side effects. If you choose to take over-the-counter medications, read and follow the directions on the label. Do not exceed the recommended dosages, and take these medications with meals or snacks to avoid heartburn. It is wise to consult your physician prior to taking any medications to assure the medication is safe and appropriate for your condition, particularly if you are taking any other medications, prescription or otherwise.

COMMON TYPES OF INJURIES

Sports medicine professionals divide injuries into two general categories, traumatic and overuse. You can think of traumatic injuries as those that are caused by a single event. Examples include an ankle sprain resulting from stepping into a hole while running or a bruise resulting from a collision with an object. Overuse injuries are not caused by a single event but rather by the accumulation of many small injuries. These small injuries would normally heal very quickly and you would hardly notice them. However, if you continue to use the injured area, the injury never heals properly and continues to worsen.[47]

TRAUMATIC INJURIES

The most common traumatic injuries are strains, sprains, contusions, and blisters. Strains or muscle pulls result when muscles are overstretched. Depending on the severity, you might feel anything from minor pain all the way up to severe pain with discoloration and a bump at the injury site. Sprains are injuries to the ligaments around a joint. Depending on the amount of tissue involved, symptoms of a sprain may extend from mild pain to marked swelling, severe pain, and excessive movement (instability) of the joint. Immediate treatment for strains and sprains involves the RICE protocol—rest, ice, compression, elevation.

Contusions are generally caused by collisions between objects and parts of the body. The body area becomes discolored and you experience localized pain. The pain and discoloration are due to the collection of blood in the muscle and surrounding tissue. The blood comes from blood vessel breakage during and shortly after the collision. Immediate treatment again involves the RICE protocol.

Foot blisters are caused by friction as the foot moves very slightly in the shoe. Since friction increases with moisture, anything you can do to reduce sweat around the foot should reduce blisters.[48] A thin polyester liner sock worn next to the skin, coupled with a wool blend outer sock, reduces blister incidence, not only because of the extra padding but because it forces moisture away from the foot.[49] In addition, a common antiperspirant (aluminum chloride hexahydrate) effectively reduces blister incidence, probably because it reduces the amount of sweat forming in the first place.[50] To be most effective, the antiperspirant should be applied for 5 consecutive nights prior to activity. Thereafter, the antiperspirant need be applied only once or twice a week to maintain the effect. If you get a blister, puncture it to release the blister fluid using a needle that has been sterilized over an open flame. Keep the top of the blister intact if possible. It protects the tender, raw flesh underneath. If the top of the blister has torn off, keep the area clean and covered and watch for signs of infection (red color or red streaks). Seek medical care if you see infection.

Less common but very serious types of injury are fractures and dislocations. Fractures are broken bones; dislocations are separations of the joint. When these injuries occur, emergency medical personnel should be consulted immediately. Splinting (immobilization) of the affected area to avoid further injury is appropriate, but only trained personnel should perform this.

OVERUSE INJURIES

Overuse injuries are much more common than traumatic injuries among physically active individuals. First aid treatment for all overuse injuries also follows the RICE protocol.

Bursitis is an inflammation of the fluid-filled sac that surrounds the joint and provides lubrication for movement. Normally there is pain as well as limitations in movement. Bursitis is often caused by acute or chronic mechanical irritation.

Tendinitis refers to an inflammation of the tendons, which hold the muscle to the bone. Although tendinitis can occur in almost any body location, one of the most common types is achilles tendinitis. This is often experienced as a painful

burning sensation in the back of the lower leg, near the heel. The pain becomes most intense when the individual moves after being sedentary for a period of time and lessens with increased activity. The pain is presumably caused by tightening and inflammation of the large achilles tendon in the back of the leg. If the condition persists, a complete break of the tendon is possible, resulting in an inability to walk. Achilles tendon injuries commonly appear in older athletes.[51] These injuries can be quite disabling; therefore, appropriate care should be taken at the first sign of symptoms.

Plantar fasciitis, sometimes called painful heel syndrome, is an inflammation of the fibrous tissue on the bottom of the foot. It is believed to be caused by a tightening of this tissue. It is often felt as heel pain and is most pronounced when you have been inactive for a long period of time, especially on arising in the morning. Pain generally lessens after the first few steps.

Runner's knee is often felt as a pain in the area below or around the kneecap. The pain increases with activity, running downhill, going up or down stairs, or sitting for a long period of time. The knee may feel unstable or give way.

Stress fractures are small hairline fractures in the bone. Normally, bone responds to exercise stress by a process called remodeling, which involves strengthening bone by removing old bone and replacing it with new bone. New bone is deposited in locations that allow the body to best tolerate the new stress. In this process, the bone is temporarily weakened (by removal of old bone) before it is made stronger (by replacement with new bone). If excessive physical activity occurs while the bone is in the weakened condition, the bone may be injured by development of the hairline breaks. Most stress fractures occur in the lower extremities, especially in the lower leg and foot. While this type of injury is less common in older athletes, it is especially serious because it threatens the structural integrity of the body.[52] If you experience bone pain that does not go away in a few days or that worsens with exercise, you should consult a health care provider.

Shin splint is a vague term used to denote pain experienced in the front part of the lower leg. A number of areas may be involved including the bones, muscles, or blood vessels. Sometimes stress fractures to the shin bones are involved. At other times, swelling of the leg as a result of inflammation is the cause of the pain. At still other times, the pain may arise from damage to blood vessels.

Injuries among Mature Recreational Athletes

Surprisingly few studies have been devoted to injuries in older recreational athletes.[53] Thus a study by Dr. Gordon Matheson and his co-workers at the University of British Columbia is useful because it compared exercise injuries of those over 50 years of age with such injuries to those under 50.[54] The major finding of this study was that the types of injury and body locations where the injuries occurred were remarkably similar between the two age groups. The most common types of injuries were tendinitis, pain under the kneecap, sprains, and strains. The most common injury sites were the knee, foot, lower leg, ankle, and shoulder. These findings are similar to ours with regard to students at the Army War College, where we found that sprains, sprains, and tendinitis were common injuries and that the knee, foot, and shoulders were very common injury sites.[55]

However, some differences did exist between the older and younger individuals in Matheson's study. On the positive side, the older athletes had fewer stress fractures, sprains, and pain around the kneecap. On the negative side, the older athletes had a higher incidence of foot pain, plantar fasciitis, and damage to the cartilage of the knee. As one ages, the reduction in strength and flexibility may reduce the shock-absorbing capabilities of the foot, resulting in changes in this area that cause pain and increase the chance of injury.[56] Injury to the cartilage of the knee may be due to small tears of this tissue over time.

The incidence of osteoarthritis was also higher in the older athletes. Osteoarthritis is a degeneration of the shock-absorbing cartilage around the joint. As one ages, this cartilage loses its elasticity and does not perform its shock-absorbing function quite as well because it becomes soft, frayed, and thinned. Other changes also occur such as muscle weakness and an undesirable growth of new bone inside and around the joint.

It was once thought that osteoarthritis was caused by the high impact forces associated with some types of physical activity (e.g. running, racquetball, softball). To test this idea, a number of studies were conducted on runners from the 1970s onward. Drs. Richard Panush and Joseph Inzinna summarized 12 investigations involving over 1,500 individuals averaging 53 years of age who ran an average of 33 miles/week for about 16 years.[57] They found that runners did not develop premature degeneration of the joints when compared to nonrunners. But when they looked at studies on other activities like baseball, ballet, cycling, football, and gymnastics there was some suggestion that these activities may increase risk. Most of these latter studies, however, were based on anecdotal information or were not well conducted. Thus running itself does not seem to increase the risk of osteoarthritis but we will have to await more information on other activities. Regular exercise is often recommended for individuals who have osteoarthritis, because it improves joint mobility and reduces the symptom of

pain and stiffness.[58]

CONCLUSIONS

Most of the injuries you may experience will be due to training errors: training too long per session, too fast, or for too many days. Exercise physiology and sports medicine have made remarkable progress in the last 30 years in identifying injury risk factors and finding ways to speed healing. As a mature recreational athlete, you have gained a unique knowledge about the capabilities and limitations of *your* body. Think of yourself as an experiment of one person. Couple the knowledge from exercise physiology and sports medicine with your personal evaluation of how much physical activity is appropriate for you. Constantly adjust your physical activity based on the exercise and sports medicine knowledge you gain, how your body feels, and your personal evaluation of what works for you.

As an athlete, you may push your body a bit to improve more, test your limits, or train for a competition; however, your body will tell you through its pain mechanisms when you have pushed too far. If you do push too far, recognize what has happened and take the appropriate steps to heal properly. Listen to the wisdom of your body and the signals it provides and then adjust your training accordingly. But most importantly, enjoy the higher quality of life that goes with an active lifestyle.

END NOTES

1. R. S. Paffenberger et al., "Physical Activity, All-Cause Mortality, and Longevity of College Alumni," *New England Journal of Medicine*, Vol. 314, 1986, pp. 605-613.

2. B. Sternfeld, "Cancer and the Protective Effect of Physical Activity: The Epidemiological Evidence," *Medicine and Science in Sports and Exercise*, Vol. 24, 1992, pp. 1195-1209.

3. K. E. Powell et al., "Physical Activity and Chronic Disease," *American Journal of Clinical Nutrition*, Vol. 49, 1998, pp. 999-1006.

4. J. J. Knapik et al., "An Investigation of Injuries Among Army Officers Attending the U.S. Army War College During Academic Year 1999," Aberdeen Proving Ground, MD: U.S. Army Center for Health Promotion and Preventive Medicine Epidemiological Consultation Report No. 29-HE-2682-99, 1999.

5. B. H. Jones, D. N. Cowan, and J. J. Knapik, "Exercise, Training, and Injuries," *Sports Medicine*, Vol. 18, 1994, pp. 202-214; J. P. Koplan et al., "An Epidemiological Study of the Benefits and Risks of Running," *Journal of the American Medical Association*, Vol. 16, 1977, pp. 31-36.

6. M. L. Pollock et al., "Effects of Frequence and Duration of Training on Attrition and Incidence of Injury," *Medicine and Science in Sports and Exercise*, Vol. 9, 1977, pp. 31-36.

7. L. I. Gardner et al., "Prevention of Lower Extremity Stress Fractures: A Controlled Trial of Shock Absorbent Insole," *American Journal of Public Health*, Vol. 78, 1988, pp. 1563-1566.

8. J. J. Knapik, et al., "Seasonal Variation in Injury Rates During a Standard Physical Activity Program," Submitted to *American Journal of Sports Medicine*, 2000.

9. B. H. Jones et al., "Epidemiology of Injuries Associated with Physical Training Among Young Men in the Army," *Medicine and Science in Sports and Exercise*, Vol. 25, 1993, pp. 197-203; and R.A. Shaffer et al., "Use of Simple Measures of Physical Activity to Predict Stress Fractures in Young Men Undergoing a Rigorous Training Program," *American Journal of Epidemiology*, Vol. 149, 1999, pp. 236-242.

10. B. H. Jones et al., "Intrinsic Risk Factors for Exercise-Related Injuries Among Male and Female Army Trainees," *American Journal of Sports Medicine*, Vol. 21, 1993, pp. 705-710; Jones et al., "Epidemiology of Injuries"; and J. J. Knapik et al., "Injury Incidence and Injury Risk Factors Among U.S. Army Basic Trainees at Ft Jackson, S.C. …," Aberdeen Proving Ground MD: U.S. Army Center for Health Promotion and Preventive Medicine Epidemiological Consultation Report No. 29-HE-8370-99, 1999.

11. Jones, et al., "Epidemiology of Injuries"; K. R. Kaufman et al., "The Effect of Foot Structure and Range of Motion on Musculoskeletal Overuse Injury," *American Journal of Sports Medicine*, Vol. 27, 1000, pp. 585-593; and J. J. Knapik et al., "Strength, Flexibility, and Athletic Injuries," *Sports Medicine*, Vol. 14, 1993, pp. 277-288.

12. W. H. Van Mechelen et al., "Prevention of Running Injuries by Warm-up Cool-Down, and Stretching Exercises," *American Journal of Sports Medicine*, Vol. 21, 1993, pp. 711-719.

13. R. P. Pope et al., "A Randomized Trial of Preexercise Stretching for Prevention of Lower-Limb Injury". *Medicine and Science in Sports and Exercise*, Vol. 32, 2000, pp. 271-277.

14. M. R. Safran et al., "The Role of Warm-up in Muscular Injury Prevention," *American Journal of Sports Medicine*, Vol. 16, 1988, pp. 123-129; and F. G. Shellock and W. E. Prentice, "Warm-up and Stretching for Improving Physical Performance and Prevention of Sports-related Injuries," *Sports Medicine*, Vol. 2, 1985, pp. 267-278; I. B. Stewart and G. G. Sleivert, "The Effect of Warm-up Intensity on Range of Motion and Anaerobic Performance," *Journal of Orthopedic and Sports Physical Therapy*, Vol. 27, 1998, pp. 154-161.

15. Knapik et al., "An Investigation of Injuries."

16. J. Ekstrand and J. Gillquist, "The Avoidability of Soccer Injuries," *International Journal of Sports Medicine*, Vol. 4, 1983, pp. 124-128; and Jones et al., "Epidemiology of Injuries."

17. G. D. Rovere et al., "Retrospective Comparison of Taping and Ankle Stabilizers in Preventing Ankle Injuries," *American Journal of Sports Medicine*, Vol. 16, 1988, pp. 228-233; S. J. Sharpe, J. J. Knapik, and B. H. Jones, "Ankle Braces Effectively Reduce Recurrence of Ankle Sprains in Female Soccer Players," *Journal of Athletic Training*, Vol. 32, 1997, pp. 21-24; and I. Surve et al., "A Five-fold Reduction in the Incidence of Recurrent Ankle Sprains in Soccer Players Using the Sports-stirrup Orthosis," *American Journal of Sports Medicine*, Vol. 22, 1994, pp. 601-606.

18. Jones et al., "Epidemiology of Injuries"; Knapik et al., "Injury Incidence and Injury Risk Factors"; A. Naus et al., "Work Injuries and Smoking," *Industrial Medicine and Surgery*, Vol. 35, 1966, pp. 880-881; and K. L. Reynolds et al., "Cigarette Smoking, Physical Fitness, and Injuries in Infantry Soldiers," *American Journal of Preventive Medicine*, Vol. 10, 1994, pp.145-150.

19. P. J. Amoroso et al., "Tobacco and Injuries: An Annotated Bibliography," Natick MA: U.S. Army Research Institute of Environmental Medicine Technical Report TN 96-1, 1996; J. J. Knapik, K. L. Reynolds, and J. Barson, "Influence of Antiperspirants on Foot Blisters Following Road Marching," Aberdeen Proving Ground, MD: U.S. Army Research Laboratory Technical Report ARL-TR-1333, 1997.

20. J. J. Knapik, U.S. Army Center for Health promotion and Preventive Medicine, EPICON Report No. 29-HE-2682-99, 1999.

21. B. H. Jones, "Injuries Among Men and Women in Gender-integrated BCT Units, Ft Leonard Wood,

1995," *Medical Surveillance Monthly Report*, Vol. 2, 1996, pp. 2-3, 7-8; Jones et al., "Intrinsic Risk Factor for Exercise Related Injuries"; Knapik et al., "Injury Incidence and Injury Risk Factors"; and D. M. Koala, "Nature and Causes of Injuries in Women Resulting from an Endurance Training Program," *American Journal of Sports Medicine*, Vol. 8, 1980, pp. 265-269.

22. K. S. Clarke and W. E. Buckley, "Women's Injuries in Intercollegiate Sports," *American Journal of Sports Medicine*, Vol. 8, 1980, pp. 187-191; R. R. Lanese et al., "Injury and Disability in Matched Men's and Women's Intercollegiate Sports," *American Journal of Public Health*, Vol. 80, 1990, pp. 1459-1462; R.A. Shively, W. A. Grana, and D. Ellis, "High School Sports Injuries," *Physician and Sportsmedicine*, Vol. 9, 1981, pp. 46-50; and S. H. Splain and A. Rolnick, "Sports Injuries at a Non-Scholarship University," *Physician and Sportsmedicine*, Vol. 12, 1984, pp. 55-60.

23. J. J. Knapik et al., "Physical Fitness, Age, and Injury Incidence in Infantry Soldiers," *Journal of Occupational Medicine*, Vol. 35, 1993, pp. 598-603; J. P. Tomlinson, W. M. Lednar, and J. D. Jackson, "Risk of Injury in Soldiers," *Military Medicine*, Vol. 152, 1987, pp. 60-64; and D. K. Wagener and D. W. Winn, "Injuries in Working Populations: Black - White Differences," *American Journal of Public Health*, Vol. 821, 1991, pp. 1408-1413.

24. D. N. Cowan, B. H. Jones, and J. R. Robinson, "Foot Morphologic Characteristics and Risk of Exercise-related Injuries," *Archive of Family Medicine*, Vol. 2, 1993, pp. 773-777; and Kaufman et al.

25. D. N. Cowan et al., "Lower Limb Morphology and Risk of Overuse Injury Among Male Infantry Trainees," *Medicine and Science in Sports and Exercise*, Vol. 28, 1996, pp. 945-952.

26. W. J. Kraemer, M. R. Deschenes, and S. J. Fleck, "Physiological Adaptations to Resistance Exercise: Implications for Athletic Conditioning," *Sports Medicine*, Vol. 6, 1988, pp. 246-256; W. D. McArdle, F.I. Katch, and V.L. Katch, *Exercise Physiology: Energy, Nutrition, and Human Performance*, Philadelphia: Lea and Febiger, 1986; and B. L. Specker, "Evidence for an Interaction Between Calcium Intake and Physical Activity on Change in Bone Mineral Density," *Journal of Bone Mineral Research*, Vol. 11, 1996, pp. 1539-1544.

27. E. C. Frederick, *The Running Body*, Mountain View, CA: World Publications, 1973.

28. D. Wathen, "Periodization: Concepts and Application," *Essentials of Strength Conditioning*, ed. T. R. Baechle, 1994.

29. Pollock et al.

30. D. C. Thompson and M. Q. Patterson, "Cycle Helmets and Prevention of Injuries," Recommendations for Competitive Sports," *Sports Medicine*, Vol. 25, 1998, pp. 213-219.

31. Centers for Disease Control and Prevention, "Injury Control Recommendations: Bicycle Helmets," *Morbidity and Mortality Weekly Report*, Vol. 44, RR-1, 1995, pp. 1-17; "CPSC Issues New Safety Standards for Bike Helmets," U.S. Consumer Product Safety Commission, Office of Information and Public Affairs Release 98-062, 1998; Thompson and Patterson.

32. T. J. Pashby, " Eye Injuries in Canadian Hockey: Phase II," *Canadian Medical Association Journal*, Vol. 17, 1997, pp. 670-678; and D. A. Webster, G. V. Boyless, and J. A. Spandero, "Head and Face Injuries in Scholastic Women's Lacrosse With and Without Eyewear," *Medicine and Science in Sports and Exercise*, Vol. 31, 1997, pp. 938-941.

33. S. M. Napier et al., "Eye Injury in Athletics and Recreation," *Survey of Ophthalmology*, Vol. 41, 1996, pp. 229-244.

34. T. H. Ellis, "Sports Protective Equipment," *Primary Care*, Vol. 18, 1991, pp. 889-921; and P. F. Vinger, "Injury Prevention: Where Do We Go from Here?" *Journal of American Optometry Association*, Vol. 70, 1999, pp. 87-98.

35. R. A. Schieber and C. M. Branche Dorsey, "In-line Skating Injuries: Epidemiology and Recommendations for Prevention," *Sports Medicine*, Vol. 19, 1995, pp. 427-432.

36. D. Lorenzten and L. Lawson, "Selected Sports Bras: A Biochemical Analysis of Breast Motion While Jogging," *Physician and Sportsmedicine*, Vol. 15, No. 5, 1987, pp. 128-139.

37. Lorenzten and Lawson; and B. R. Mason, K. A. Page, and K. Fallon, "An Analysis of Movement and Discomfort of the Female Breast During Exercise and the Effect of Breast Support in Three Cases," *Journal of Science and Medicine in Sports*, Vol. 2, 1999, pp. 134-144.

38. K. A. Page and J. R. Steele, "Breast Motion and Sports Brassiere Design: Implications for Future Research," *Sports Medicine*, Vol. 27, 1999, pp. 205-211; and B. Stamford, "Sports Bras and Briefs: Choosing Good Athletic Support," *Physician and Sportsmedicine*, Vol. 24, 1996, pp. 99-100.

39. D. H. Janda, F. M. Hankin, and E. M. Wojtys, "Softball Injuries: Cost, Cause, and Prevention," *American Family Physician*, Vol. 33, 1986, pp. 143-144; and M.T. Nadeau et al., "The Prevention of Softball Injuries: The Experience at Yokota," *Military Medicine*, Vol. 155, 1990, pp. 3-5.

40. D. H. Janda, D. E. Wild, and R. N. Hensinger, "Softball Injuries: Aetiology and Prevention," *Sports Medicine*, Vol. 13, 1997, pp. 285-291; and D. H. Janda et al., "A Three-phase Analysis of the Prevention of Recreational Softball Injuries," *American Journal of Sports Medicine*, Vol. 18, 1990, pp. 632-635.

41.R. A. Sendre et al., "Use of the Hollywood Impact Base and Standard Base to Reduce Sliding and Base Running Injuries in Baseball and Softball," *American Journal of Sports Medicine*, Vol. 22, 1994, pp. 450-453.

42. Grundewall et al., "Primary Prevention of Back Symptoms and Absence from Work: A Prospective Randomized Study Among Hospital Employees," *Spine*, Vol. 18, 1993, pp. 587-594; F. R. Hansen et al., "Intensive, Dynamic Back Muscle Exercises, Conventional Physiotherapy, or Placebo Control Treatment of Low Back Pain - A Randomized, Observer Blind Trial," *Spine*, Vol. 18, 1993, pp.98-108; B. Nelson et al., "The Clinical Effects of Intensive, Specific Exercise on Chronic Low Back Pain: A Controlled Study of 895 Consecutive Patients with One Year Follow-up," *Orthropedics*, Vol. 18, 1995, pp. 971-981; P.B. O'Sullivan et al., "Evaluation of Specific Stabilizing Exercise in the Treatment of Chronic Low Back Pain with Radiologic Diagnosis of Spondylosis or Spondylolisthesis," *Spine*, Vol. 22, 1997, pp. 2959-2967; and J. A. Saal, "Nonoperative Treatment of Herniated Lumbar Intervertebral Disc with Radiculopathy: An Outcome Study," *Spine*, Vol. 14, 1989, pp. 431-437.

43. D. M. Kahler, "Low Back Pain in Athletes," *Journal of Sports Rehabilitation*, Vol. 2, 1993, pp. 63-78.

44. J. W. Frymoyer and W.L. Cats-Baril, "An Overview of the Incidences and Costs of Low Back Pain," *Orthopedic Clinics of North America*, Vol.22, 1991, pp. 263-271; D. M. Kahler, "Low Back Pain in Athletes," *Journal of Sports Rehabilitation*, Vol. 2, 1993, pp. 63-78; A. L. Nachemson, "The Lumbar

Spine: an Orthopedic Challenge," *Spine*, Vol. 1, 1976, pp. 59-71; and D. H. Saunders, *Evaluation, Treatment, and Prevention of Musculoskeletal Disorders*, Minneapolis, MN: Viking Press, 1985.

45. D. Wohlfahrt et al., "The Relationship Between the Dynamic and Static Function of Abdominal Muscles," *Australian Journal Physiotherapy*, Vol. 39, 1993, pp. 9-13.

46. B. H. Jones et al., "Exercise-related Musculoskeletal Injuries: Risks, Prevention, and Care," *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription*, eds. J. L. Durstine et al., American College for Sports Medicine, 1993, pp. 378-393.

47. D. D. Arnheim and W. E. Prentice, *Principles of Athletic Training*, St. Louis: Mosby Year Book, 1993; Jones et al., "Exercise-related Musculoskeletal Injuries"; and A. F. Morris, *Sports Medicine Handbook*, Dubuque, IA: W.C. Brown, 1984.

48. W. A. Akers and M. B. Sulzberger, "The Friction Blister," *Military Medicine*, Vol. 137, 1972, pp. 1-7.

49. J. J. Knapik et al., "Influence of Boot Sock Systems on Frequency and Severity of Foot Blisters," *Military Medicine*, Vol. 161, 1996, pp. 594-598.

50. J. J. Knapik, K. Reynolds, and J. Barson, "Influence of An Antiperspirant on Foot Blister Incidence During Cross Country Hiking," *Journal of the American Academy of Dermatology*, Vol. 39, 1998, pp. 202-206.

51. M. Kallinen and A. Markku, "Aging, Physical Activity, and Sports Injury: An Overview of Common Sports Injury in the Elderly," *Sports Medicine*, Vol. 20, 1995, pp. 41-52.

52. G. O. Matheson et al., "Musculoskeletal Injuries Associated with Physical Activity in Older Adults," *Medical Science and Sports Exercise*, Vol. 21, 1989, pp. 379-385.

53. Kallinen and Markku.

54. Matheson et al.

55. Knapik et al., "An Investigation of Injuries."

56. D. A. Brown and W. C. Miller, "Normative Data for Strength and Flexibility of Women Throughout Life," *European Journal of Applied Physiology*, Vol. 78, 1998, pp. 72-82; and M. J. G. Van Heuvelen et al., "Physical Fitness Related to Age and Physical Activity in Older Persons," *Medicine and Science in Sports and Exercise*, Vol. 30, 1998, pp. 424-441.

57. R. S. Panush and J. D. Inzinna, "Recreational Activities and Degenerative Joint Disease," *Sports Medicine*, Vol. 17, 1994, pp. 1-5.

58. N. A. DiNubile, "Osteoarthritis: How to Make Exercise a Part of Your Treatment Plan," *Physician and Sportsmedicine*, Vol. 25, No. 7, 1997, pp. 47-56.